

Refractivity-from-Clutter

Ted Rogers
SPAWARSCEN PACIFIC 5528
Atmospheric Propagation Branch
49170 Propagation Path
San Diego, CA 92152-7385
phone: (619) 553-1416 fax: (619) 553-1417 email: ted.rogers@navy.mil

Award Number: N0001412AF00002

LONG TERM GOALS

Advance technical readiness of refractivity-from-clutter (RFC) technologies [1, 2 and 3] to support acceptance into a program-of-record (POR).

OBJECTIVES

Conduct a measurement campaign to collect concurrent meteorological and radar data to support validation of the capability of the RFC surface-based duct algorithm (RFC-SBD) [1 and 2] on the SPS-48 radar. Along with Naval Research Laboratory (NRL), Monterey, continue engagement with internally-funded effort at Scripps Institution of Oceanography (SIO) on development of methods for fusing data from RFC [1, 2, and 4] with background fields from a numerical weather prediction (NWP) model.

APPROACH

A measurement campaign was designed to coincide with June availability of Naval Surface Warfare Center, Dahlgren Division's (NSWC-DD's) Surface Combat Systems Center (SCSC) SPS-48 system located at Wallops Island Virginia. To support collection of the data from the SPS-48, a spare Hazardous Weather Detection and Display Capability (HWDDC) system – a system that transforms raw data from the SPS-48 into universal format (“.uf”) files – was installed on the Wallops SPS-48. The Naval Postgraduate School was contracted to provide radiosonde launches (4 per day) from a beach location at SCSC, as well as placing a meteorological buoy approximately 4 miles off-shore from the radar's location. As a back-up plan (subsequently proven prescient), arrangements were made through SCSC to purchase approximately 2 hours / day of radar observations time with the National Aeronautical and Space Administration (NASA) Goddard Space Flight Center's (GSFC) Space Range Radar (SPANDAR).

The data fusion effort was performed by PhD student Ali Karimian (under Dr. Caglar Yardim and Dr. Peter Gerstoft at SIO). NRL Monterey (Tracy Haack) provided ensemble runs from the Coupled Ocean and Atmospheric Mesoscale Prediction System (COAMPS). The work evaluated the merits of performing the data fusion operations in the space of air temperature (Ta) and relative humidity (RH) at a reference height, vice an evaporation duct height based on a an assumption of a log-linear

Report Documentation Page			Form Approved OMB No. 0704-0188					
<p>Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.</p>								
1. REPORT DATE 2012	2. REPORT TYPE N/A	3. DATES COVERED -						
4. TITLE AND SUBTITLE Refractivity-from-Clutter			5a. CONTRACT NUMBER					
			5b. GRANT NUMBER					
			5c. PROGRAM ELEMENT NUMBER					
6. AUTHOR(S)			5d. PROJECT NUMBER					
			5e. TASK NUMBER					
			5f. WORK UNIT NUMBER					
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) SPAWARSCEN PACIFIC 5528 Atmospheric Propagation Branch 49170 Propagation Path San Diego, CA 92152-7385			8. PERFORMING ORGANIZATION REPORT NUMBER					
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)			10. SPONSOR/MONITOR'S ACRONYM(S)					
			11. SPONSOR/MONITOR'S REPORT NUMBER(S)					
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release, distribution unlimited								
13. SUPPLEMENTARY NOTES The original document contains color images.								
14. ABSTRACT								
15. SUBJECT TERMS								
16. SECURITY CLASSIFICATION OF: <table border="1"> <tr> <td>a. REPORT unclassified</td> <td>b. ABSTRACT unclassified</td> <td>c. THIS PAGE unclassified</td> </tr> </table>			a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified	17. LIMITATION OF ABSTRACT SAR	18. NUMBER OF PAGES 4	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified						

evaporation duct refractivity profile (as has usually been used in RFC work and had been suggested by the author). A sub-optimal 2DVAR was implemented ensemble COAMPS runs for the vicinity of Hawaiian Islands and synthetic clutter observations were generated from the ensemble mean prediction model output and synthetic observations of radar clutter. The output was evaluated in the space of meteorological parameters, the evaporation duct height, and the effect on propagation.

RESULTS

SCSC's SPS-48 system developed problems with its two final stages of amplification shortly after the installation of the HWDDC system. Repairs could not be effected until a "grooming" event with the NSWC's Dam Neck Division that would not occur until after the observation period ended. In addition to the problem with the SPS-48, the Naval Postgraduate School's buoy failed a few days into the test. With these two failures, the yield from the exercise is limited to a coordinated set of radar observations (using the SPANDAR), shore-located surface layer observations, and up-down radiosondes over the period from 11-to-28 June.

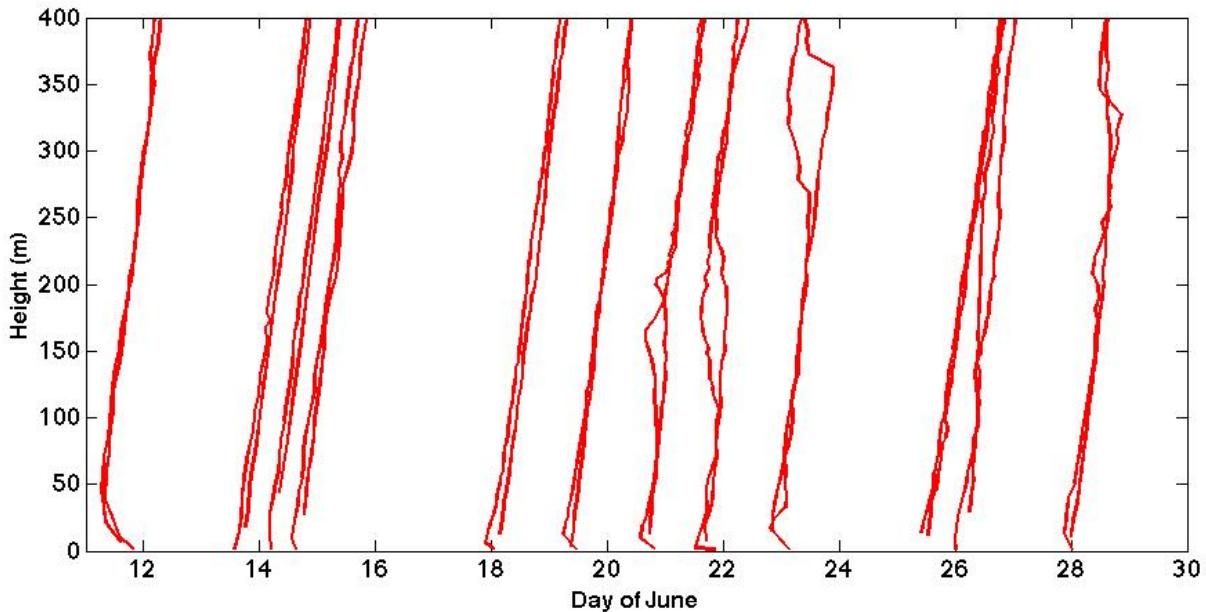


Figure 1. Refractivity Profiles from Wallops Island 11-28 June, 2012. X-axis is the day in June while the Y-axis is the height in meters above sea level.

A time series of a representative subset of the refractivity profiles obtained is shown in Figure 1. Indications of a low surface duct is seen in the sounding of the 11th and possibly in the sounding on the 21st. Overall, though, the period of time of the experiment did not provide the degree of ducting that had been expected given the climatology for Wallops Is. Based on our observations of the SPANDAR while the data collection was taking place, relatively high (i.e., > 14m) evaporation duct heights were the norm during the observations, accompanied by light and variable winds.

The SPANDAR was operated using horizontal polarization, which is the same as the SPS-48. We will use SPANDAR data as a proxy for SPS-48 data by injecting noise into the SPANDAR data so as to reduce the clutter-to-noise ratio (CNR) to a level consistent with the SPS-48. Currently the data from

the SPANDAR is being converted from its native format (“raw”) into a format that can be consumed by the RFC processing tools. Using SPS-48 “proxy” data (i.e., SPANDAR observations with noise injected to emulate the SPS-48) we can assess the observability of clutter under light / variable winds. This in turn is a key factor in determining the operational utility of implementing RFC (for both evaporation ducts and surface based ducts) on the SPS-48. It is unclear (just yet) how precise of a picture of the surface layer can be constructed from the observations at hand.

The key result of the data fusion work is that in the space of the key meteorological parameters the combining is performed in, the ambiguity of the RFC-ED inversions does not align with the uncertainty of the NWP ensemble output. In Figure 2, the plot on the lower left shows the joint *a priori* distributions of air-sea temperature difference (ASTD) and relative humidity (RH) at a point in horizontal space based on the COAMPS ensemble. The marginal distributions are shown immediately above and immediately to the right for ASTD and RH respectively. Three plots to the right of the first group show the *a posteriori* distributions for these same quantities based on refractivity-from-clutter for evaporation ducts (RFC-ED) implemented on clutter synthesized from the ensemble mean. The implication is that the information sources are complementary to each other.

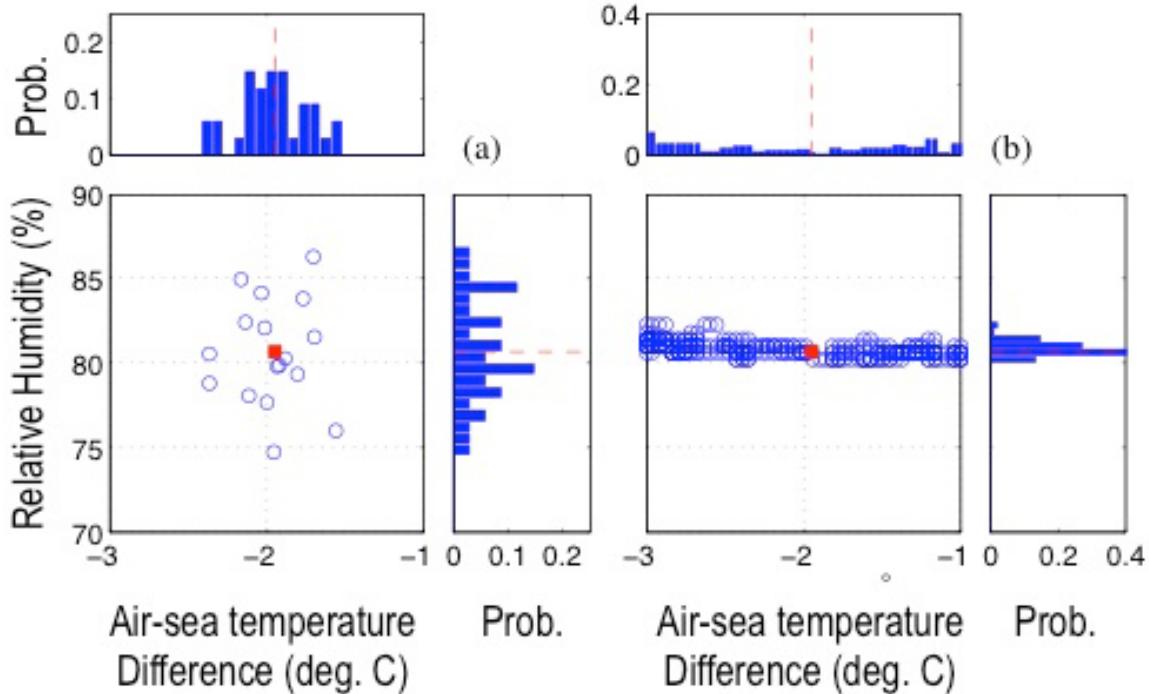


Figure 2. Joint and Marginal Distributions of COAMPS ensemble predicted (left plots) and RFC-ED inferred (right plots) Air-sea Temperature Difference (deg. C) and Relative Humidity (%).

As with all simulations, what is shown here should be taken “with a grain of salt.” The next logical steps include:

1. Test with actual data including that described earlier.

2. Inject slope contamination in the RFC process (i.e., varying degrees of increase or decrease in the sea clutter radar cross section with respect to range).

3. Examine the potential impact on determination of moisture and temperature fluxes through the surface layer.

IMPACT/APPLICATIONS

The data collection will provide new data for evaluation and development of RFC and data fusion technologies.

TRANSITIONS

RFC algorithms are expected to be transition into the Naval Integrated Tactical Environmental Subsystem (NITES) EM module or into the HWDDC processor.

It should be noted that with the implementation of NITES Next and an inherent ability to communicate with the HWDDC processor on the SPS-48, the cost barrier for implementing RFC or refractivity data fusion technologies has been significantly reduced.

RELATED PROJECTS

None.

REFERENCES

1. Karimian, Ali, Caglar Yardim, Peter Gerstoft, William S. Hodgkiss, Amalia E. Barrios (2011), Refractivity Estimation from Sea Clutter: An invited review, *Radio Science*, RS6013, doi:10.1029/2011RS004818.
2. Rogers, L Ted, Mike Jablecki, and Peter Gerstoft, Posterior distribution of a statistic of propagation loss estimated from radar sea clutter, *Radar Science*, Vol. 40, RS6005, doi:10.1029/2004RS003112, 2005.
3. Rogers, L. T., C. P. Hattan, and J. K. Stapleton (2000), Estimating evaporation duct heights from radar sea echo, *Radio Sci.*, 35(4), 955–966, doi:10.1029/1999RS002275.
4. Burk, S.D., T. Haack, L.T. Rogers, and L.J. Wagner, 2003: Island wake dynamics and wake influence on the evaporation duct and radar propagation. *J. Appl. Meteor.*, **42**, 349-367.

PUBLICATIONS

A paper describing the refractivity data fusion work will be submitted to an appropriate journal in October 2012.